Improved Aviation Security via Technology Advancements

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Efforts to improve and advance airport baggage and passenger screening systems by applying advanced technology are paving the way for safer air travel.

In the years following the September 11, 2001 attacks, commercial passenger flights have continued to be high-priority targets for attempted terrorist strikes using explosives. From failed "shoe bomber" Richard Reid in December 2001, to the foiled plot to attack multiple flights using smuggled liquid explosives during summer 2006, to the attempted "underwear bomber" on Christmas Day 2009, terrorists have shown considerable ingenuity in trying to sneak explosive devices onto planes. Defending against such efforts is a high priority for the Transportation Security Administration (TSA) and the Department of Homeland Security (DHS). DHS has contracted LLNL to assist in the development and procurement processes for advanced technology for improved aviation security. President Obama has asked the national labs, including LLNL, to increase their efforts related to national security (Figure 1).

Prior to 9/11, screening devices at airports (e.g., metal detectors and baggage x-ray scanners) were employed primarily to detect knives and guns. After 9/11, additional devices were deployed to detect explosives in checked baggage. This additional equipment included specially designed computed tomography (CT) scanners for detecting bulk explosives as well as equipment for detecting explosive traces. In response to some of the previously noted attempted attacks, pilot programs have been undertaken to install equipment to detect threats in shoes, find liquid explosives in carry-on baggage, and find threats concealed under passengers' clothing.

Current explosives detection systems operate by scanning for certain material characteristics, such as the mass and atomic number of explosive components. However, some innocuous materials share the same characteristics found in threats, resulting in imprecise scanning results and many false alarms. These false alarms necessitate additional manual screening of baggage, passengers, and other divested objects, leading to greater labor expense, operator fatigue, additional space requirements to conduct added screening, and passenger inconvenience. The demonstrated ingenuity of terrorists emphasizes the need for detecting even more potential threats, which might cause even more false alarms.

There is a great need to improve the accuracy of presently deployed detection equipment, identify additional material characteristics that can be used to differentiate threats from non-threats, and discover additional methods for examining passengers and baggage that can lead to development of next-generation equipment. DHS asked LLNL to work

"On December 27, 2009, I directed that an immediate review of aviation screening technology be initiated. This review should be led by the Department of Homeland Security, working with other departments and agencies **including the Department of Energy and the National Laboratories....**"

Barack Obama
White House Press
Release, December 29, 2009

Figure 1. **Portion of the Presidential Memorandum of December 29, 2009, directing the National Laboratories to assist in reviewing and improving aviation security.**

Figure 2. (a) An example of an x-ray carry-on luggage inspection system. (b) A sample x-ray scan image showing threats and non-threats in bottles in a suitcase. The dashed bounding boxes are keys provided by LLNL. The solid dark blue outlines are the segmentation boundaries from a third-party algorithm. The yellow line is the major axis of a detected item. Red ovals highlight overlapping objects.

on these goals and their component challenges based on our unique experience and understanding in the areas of algorithm development and materials characterization. This experience and understanding comes from LLNL's long history of researching, developing, and applying similar techniques in our weapons and stockpile stewardship work. In adapting this knowledge to airport security, DHS has requested that our work be applicable to checked baggage, carry-on baggage and divested objects at checkpoints, whole-body imaging (now known as advanced imaging technology), and standoff detection. The results of our work are helping to inform third-party vendors, who manufacture detection systems, and the TSA, who will use the knowledge to make policy decisions.

In order to increase the accuracy of current commercial detection equipment, it must be made "smarter" and more sensitive. For x-ray scanning equipment, we are conducting fundamental research to characterize the x-ray properties of threats (i.e., explosives and their various component materials) and prevalent non-threat materials (i.e., bottled water, food items, toiletries, etc.) and store the results in a database (see Figure 2). This data is then being used to predict the impact on false alarm rates when newly identified threat materials need to be detected. The results are also used to find additional features that can aid in distinguishing threats from non-threats. Ultimately, in partnership with government agencies, vendors, and third parties, this information will be used to develop advanced algorithms such as automated target recognition (ATR) and reconstruction algorithms.

In one example of the application of this research, LLNL scanned explosives on two commercial x-ray projection scanners at Tyndall Air Force Base in Florida. The resulting images were archived in LLNL's database and then provided to several third parties along with a technical statement of work. The third parties developed ATRs, which were independently evaluated by LLNL. At least two of the third parties are now working with vendors to commercialize their ATRs so that they can be incorporated into a new generation of x-ray scanners.

The precision of the features used by an ATR is a function of the quality of the images generated by a scanner. The CT-based security scanners presently deployed rely mainly on image reconstruction algorithms that were developed for medical imaging applications; hence, these algorithms have not been optimized for use in an airport security setting. As shown in Figure 3, streak artifacts can reduce performance in CT images of scanned baggage. To increase accuracy, LLNL is investigating two

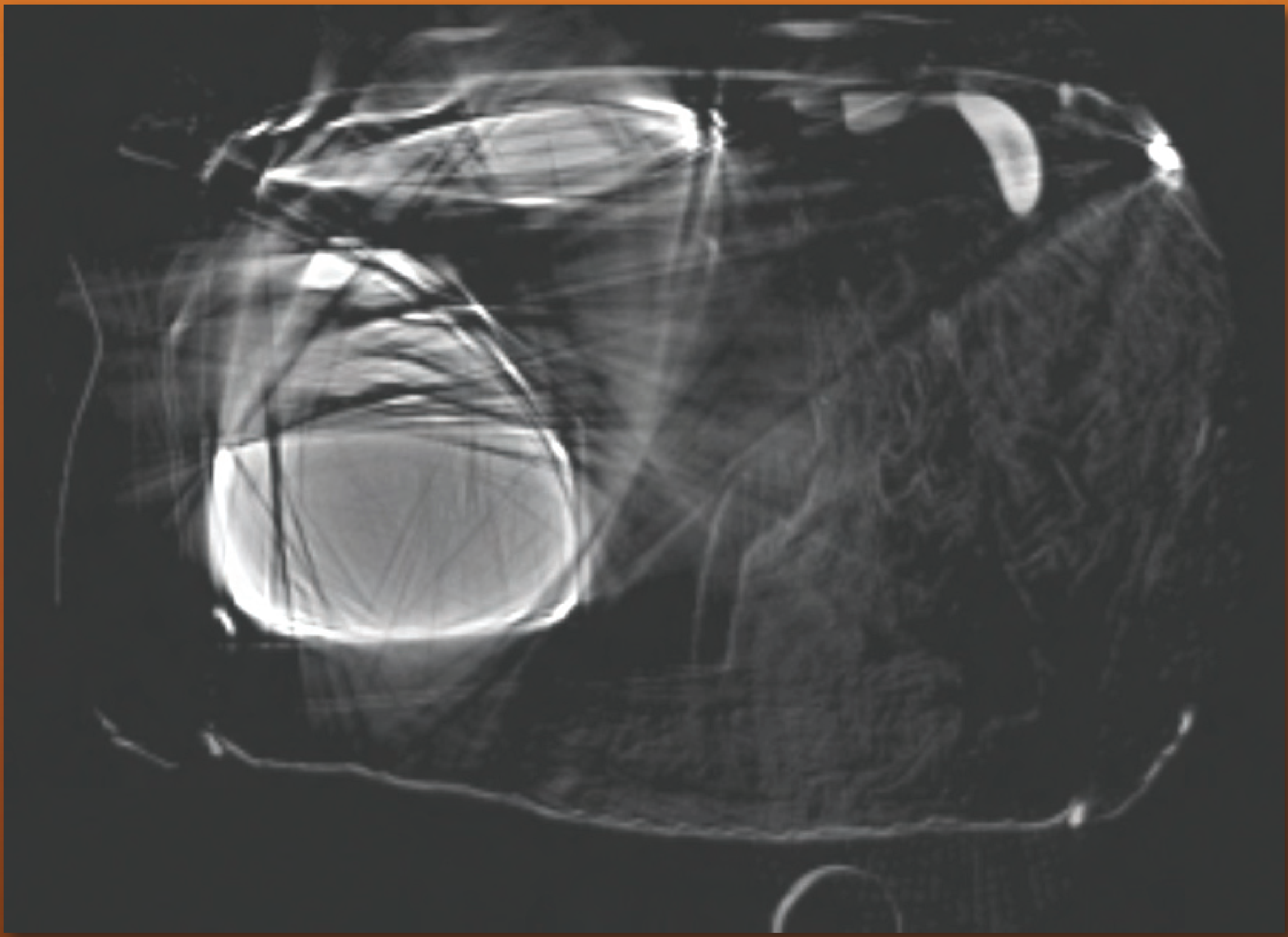

Figure 3. Streak artifacts can be a problem in CT images, as shown above.

iterative image reconstruction methods that can help reduce, if not eliminate, streaks. Our efforts have helped speed and improve both methods, and both can be used to reduce streak artifacts and improve the quality of images derived from scanner data (Figure 4).

As work in both government and commercial arenas continues to improve scanner technology, LLNL is helping to codify standards for these devices, providing technical guidance to a standards organization to develop a common format for data and images from security scanners. We are also pinpointing capability gaps in current equipment and actively reviewing literature and patents and engaging with colleagues at other national labs, academia, and industry to identify new technologies that could improve existing equipment or lead to new scanning methods. This work is enabling TSA, DHS, and airport security officials in their efforts to stay a step ahead of terrorists.

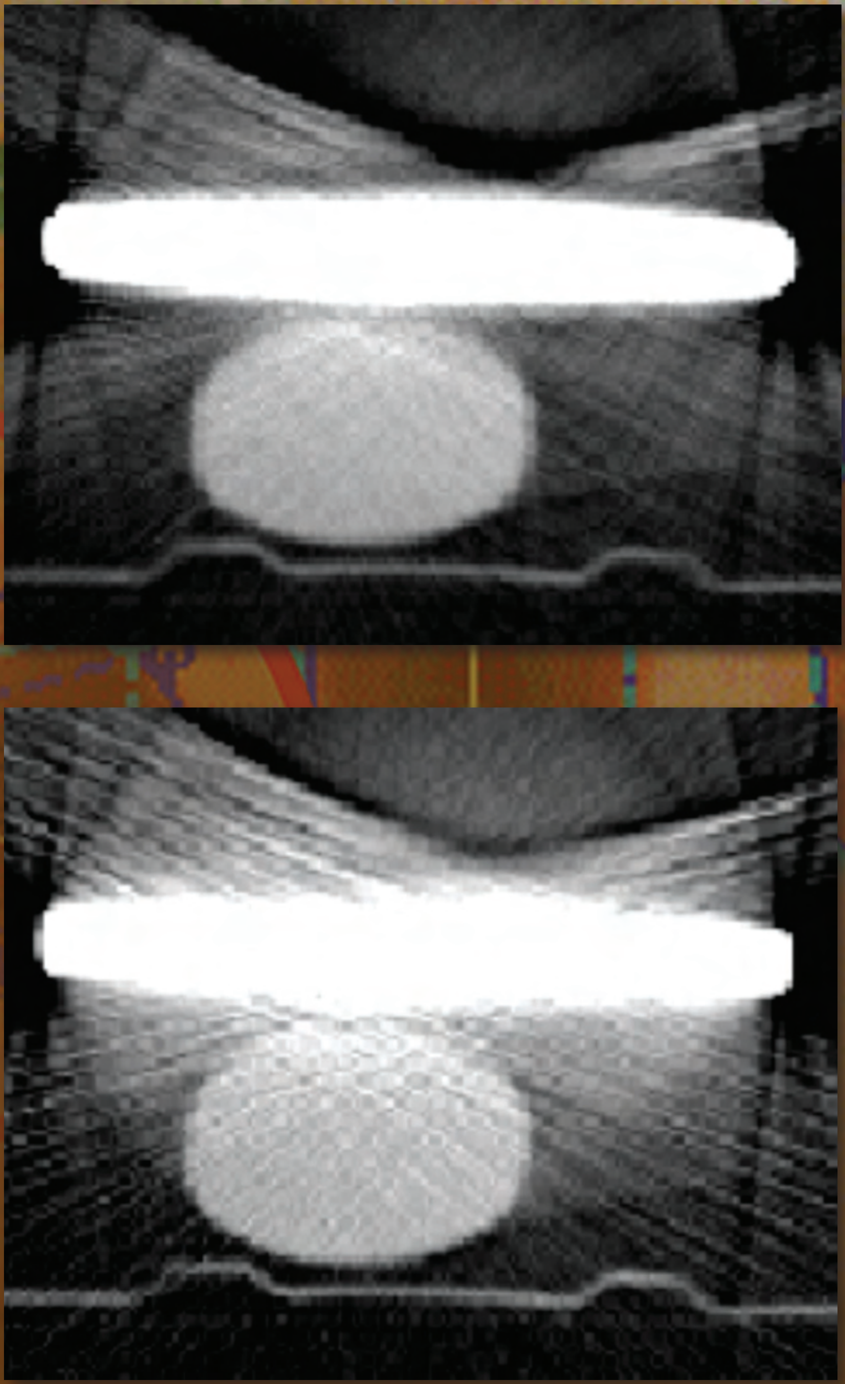

Figure 4. **We are investigating iterative image reconstruction methods, such as an adjoint method (top) and traditional Filtered Back Projection (bottom). Both of these techniques reduce streak artifacts, improving the quality of scanner data and enabling more accurate results.**